Table 2. General Response Actions and Potential Applicable Technologies - Soil

General Response Action	Remedial Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Potential for Retain for Further Evaluation
No Further Action	None	None	No further action to address contaminated soil and sediment.	Will not address the remedial objectives.	None	None	Yes as baseline for evaluation process
Institutional Controls	Access and Use Restrictions	Land Use Controls	Land use restriction (i.e., deed notice or restrictive covenant) is issued for properties located in the contaminated areas to restrict the land use to either residential or industrial / commercial only pending on EPA decision.	Will prevent direct exposure to the contaminants; therefore it will address relevant remedial objectives.	Implementable	Low	Yes
Containment	Consolidation and Capping	Clay Cap, Synthetic Membrane, or Chemical Sealant or Stabilizer	A cap is installed to cover the contaminated area to prevent direct exposure to the contamination. Different materials can be used for the cap and typical materials include clay, synthetic membranes, and chemical sealants or stabilizers. Contaminated soil can be consolidated in one area and capped.	Will prevent direct contact and exposure to the contaminated soil , although it does not remove the source of the contamination. It will address the relevant remedial objectives.	Implementable with commercially available equipment; potential worker and community exposure to dust; administrative controls will be required.	Medium	Not as a stand-alone technology and it is included in containment cell option
Removal	Excavation and Disposal	Excavation and Onsite Disposal	Contaminated soil is excavated and placed in a containment cell which may consist of a bottom liner and a cap. Bottom liner may consist of, from bottom to top a impermeable liner, leach collection layer, a protection layer overlain by excavated contaminated soil. A cap may consist of an impermeable layer, an infiltration collection layer, and soil cover and vegetation.	Will prevent direct contact and exposure to the contaminated soil , and contain the contaminated materials in a cell. It will address the relevant remedial objectives.	Implementable with commercially available equipment. Potential worker and community exposure to dust during the construction, therefore dust controls will be required. A deed notice is required to control the future land use and protect the integrity of the cell.	Medium, but the quantity of the contaminated soil is relatively low, so building a small containment cell might not be cost effective because of a low ratio of waste quantity versus cell construction materials.	Yes
		Excavation and Offsite Disposal	Contaminated soil are excavated and transported to a permitted offsite facility for disposal.	Will remove the contaminated soil from the site. It will address the relevant remedial objectives.	Implementable	Medium	Yes
Treatment	*Ex situ* Physical, Chemical Treatment	Excavation and Chemical Oxidation	Oxidizing agents (Fenton's reagent, permanganate, ozone, and hypochlorites) are added into the excavated soil to promote abiotic destruction of contaminants. Treated soil is placed back to the excavations	Chemical oxidation will destroy the contaminants to become less toxic; however some metals (chromium) may become mobile once being oxidized and may impact the groundwater.	Implementable, and a bench scale testing is required to determine oxidant dosage.	High, can be cost prohibitive if the soil contains high organic matter.	No, due to potential mobilization of metals to the groundwater
		Excavation and Soil Mixing and Stabilization/Solidification	Reagents are mixed with excavated soil by a mechanical mixing device to trap, treat, or immobilize contaminants. Treated soil is placed back to the excavations and covered by clean soil and vegetation. Reagents may include cement, bentonite, activated carbon.	Will stabilize and reduce contaminants' migration. However the treated soil is required to be protected from excavation, drilling, and other earthmoving activities. Institutional controls are required to protect the treated soil.	Implementable with commercially available equipment; treatability study is required to determine reagent dosing; may take longer time to treat; potential worker exposure is present during construction, especially during materials handling.	High	No, due to high cost
		Excavation and Soil Washing	Contaminants in soil are desorbed by using a solution of leaching agent, surfactant, pH adjustment, or chelating agent to help remove the contaminants and fine materials on which the contaminants absorbed.	Will address the remedial objectives by removing the contaminants from the soil .	Complex process and produces a large quantity of process water that requires treatment. Acid reagent may be used to remove lead from soil, which increase the health and safety concern during the implementation.	High	No, due to complex implementation and cost
		Excavation and Thermal Treatment	Heat is applied to the excavated soil to increase the volatility of the contaminants. An off-gas treatment will be used to treat the volatilized PAHs and lead. *Ex situ* thermal treatment technologies include hot gas decontamination, incineration, thermal desorption, and vitrification, which is a high-temperature treatment to immobilize contaminants by incorporating them in the vitrified end product.	Will destroy the contaminants (i.e., lead and PAHs), so it will address the remedial objectives.	Not readily implementable, treatability studies required; significant materials handling; specialized equipment and operators; extended construction/ treatment period (6-7 months); viscous nature may require pre-treatment; potential community opposition; potential combination with other technology for residual management; onsite management of residuals will need institutional controls.	High	No, due to complex implementation and cost
		Landfarming	Landfarming is used for the biological treatment of contaminated soil. It consists of spreading excavated contaminated soil either directly on the ground or on a membrane with an upper protective layer to prevent contaminants from migrating to the soil underneath and to the groundwater. Mixing or tilling of the contaminated soil is normally required to blend nutrients/amendments, and distribute moisture to promote biodegradation of the contaminants. Periodical watering is also required to provide optimal condition for microbial activities.	Landfarming is typically applicable to nonvolatile and semi- volatile compounds. Biodegradation of PAHs becomes more difficult as the number of aromatic rings increase. Therefore landfarming typically is not considered to be effective for treating PAHs that contain more than four rings, i.e., benzo(a)pyrene. It is not certain with currently available data if landfarming will be effective for treating lead in soil.	Implementable, however it may take a long period of time depending on biodegradation process in the soil.	Low	No due to ineffectiveness for PAHs with more aromatic rings and lead
	In Situ Treatment	*In Situ* Stabilization/Solidification	Contaminated soil is mixing in place with reagents to form a solid with certain strength and low permeability to immobilize contaminants or reduce contaminants to a less toxic form. Reagents may include Portland cement, lime, fly ash, organoclay, activated carbon, and bentonite.	May stabilize both organic and metal contaminants. Will need institutional controls to protect the treated soil from excavation, drilling, and other earthmoving activities. Institutional controls are required to protect the treated soil. However, the soil contamination is relatively shallow therefore, *in situ* stabilization is not cost effective.	Implementable with commercially available equipment; treatability study is required to determine reagent dosing; may take longer time to treat.	High	No due to high cost
		Phytoremediation	Plants are used to remove, transfer, stabilize and destroy contaminants in soil. Biodegradation takes place in the soil immediately surrounding plant roots; plant roots can also accumulate and stabilize contaminants in the soil.	Effectiveness of phytoremediation can be seasonal; in some cases it is limited to shallow soil. It is uncertain if the contaminant concentrations are tolerant or toxic to plants.	Implementable	Low	No, due to uncertainty of effectiveness

NOTE:

COC = Contaminant of concern
ISTD = *In Situ* Thermal Desorption
CO = *In situ* chemical oxidation
RH = Electrical resistive heating
SVE = Soil vapor extraction
MNA = Monitored natural attenuation
Polycyclic aromatic hydrocarbon